NON-INVASIVE SURVEY OF FOREST CARNIVORES IN THE NORTHERN CASCADES OF OREGON, USA

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ABSTRACT—Several species of forest carnivores are of state or federal concern in Oregon and are or may be sensitive to timber management practices, wildfires, climate change, and other large-scale disturbances. We implemented a non-invasive survey of forest carnivores in the northern Cascades of Oregon during fall–spring, 2012–2014. We collected 111,148 images from 21 elevated and 39 ground-level baited camera stations located from 586 to 2237 m in elevation. We detected (≥1 image) Red Fox (Vulpes vulpes) at 9 ground stations, of which 4 also detected Coyote (Canis latrans). We detected American Marten (Martes americana) at 63% of all stations (elevation range = 1252–2237 m), including 5 of 7 stations located in areas that experienced wildfires since 1996 that covered >5000 ha. Other forest carnivores detected included Bobcat (Lynx rufus), Black Bear (Ursus americanus), Mountain Lion (Puma concolor), Northern Raccoon (Procyon lotor), American Mink (Neovison vison), weasel (Mustela spp.), and skunk (Mephitis mephitis, Spilogale gracilis); but we did not detect Wolverine (Gulo gulo), Canada Lynx (Lynx canadensis), Fisher (Martes pennanti), or Gray Wolf (Canis lupus). Future periodic non-invasive surveys of forest carnivores may provide information about changing species composition and distribution, especially in relation to climate change, vegetation succession, and potential recolonization by Gray Wolves.

Key words: American Marten, camera survey, carnivore, Cascades, Gulo gulo, Martes americana, Martes caurina, Sierra Nevada Red Fox, Oregon, Vulpes vulpes necator, Wolverine

Several species of forest carnivores in the Pacific Northwest (OR, WA) are considered sensitive because there is evidence of significant current or predicted decreasing trends in population abundance or in existing distribution of the species of interest (US Forest Service 2005). Factors considered detrimental to many forest carnivore species include forest fragmentation through clear-cutting, landscape-scale wildfires, and climate change (Ruggiero and others 1994; McKelvey and others 2011). Carnivore species that may be particularly susceptible to such large-scale disturbances include Sierra Nevada Red Fox (Vulpes vulpes necator), Wolverine (Gulo gulo), and American Marten (Martes americana).

Two indigenous subspecies of Red Fox occupy Oregon, but non-native Red Foxes (e.g., eastern U.S. subclade) are also present in Oregon (Statham and others 2012). The native Rocky Mountain Red Fox (V. v. macroura) is distributed in montane systems within many Rocky Mountain states, and extends into the Wallowa Mountains in northeastern Oregon (Ables 1975). In Oregon, the native Sierra Nevada Red Fox was lumped with the Cascades subspecies (V. v. cascadensis) of Washington until recent evidence suggested the current classification based on their closer phylogenetic relationship with Sierra Nevada Red Fox in California (Sacks and others 2010). This montane subspecies was once widespread throughout high-elevation areas of California in the southern Cascades and the Sierra Nevada, but its distribution in Oregon is largely unknown. In California, there are only 2 known populations with total numbers estimated to be <50 individuals (Statham and others 2012). Sympatric Coyotes (Canis latrans) may compete with and exhibit
agonistic behavior toward Red Foxes, although this is largely unknown for montane subspecies (Perrine 2005). The Sierra Nevada Red Fox was petitioned for listing under the federal Endangered Species Act (ESA) during 2011, with a listing determination currently under review (US Fish and Wildlife Service 2011).

In 1936, the Wolverine was thought to have been extirpated from Oregon; however, there has been at least 1 record per decade during 1960–1999 based on information collected by the Oregon Department of Fish and Wildlife ([ODFW]; Hiller 2011). Three individuals were detected in the Eagle Cap Wilderness during a 2011–2012 survey in northeastern Oregon, although there was no evidence that any of these individuals were female (Magoun and others 2013). Wolverines have been protected in Oregon since 1967, were listed as threatened under the Oregon ESA in 1987, and at the time of this writing, were not considered threatened in the contiguous US under the federal ESA (US Fish and Wildlife Service 2014).

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Habitat for American Marten typically includes late successional coniferous and mixed forests with >30% canopy cover (see Clark and others 1987; Strickland and Douglas 1987). The Pacific Northwest has experienced intensive logging during the past century and the distribution of martens in this region is largely discontinuous because of fragmented patches of forest cover (Gibilisco 1994). Based on state agency harvest data, the average annual number of martens harvested in the Oregon Cascades (and statewide) has decreased substantially during recent decades, but disentangling the potential factors such as decreasing abundance and decreasing harvest effort causing changes in harvest levels continues to prove difficult (Hiller 2011; Hiller and others 2011).

We implemented a 2-y non-invasive survey to collect data on forest carnivores in the Oregon Cascades. We concentrated our efforts in wilderness areas specifically to collect presence and distribution data using baited camera stations for Red Fox, Wolverine (if present), and American Marten, but also to collect hair and scat samples for DNA analysis for Red Fox and Wolverine. Our objective with this paper is to describe our detections of forest carnivores, with additional efforts to provide more detailed information on Red Fox. We also describe published and unpublished information on relatively rare forest carnivores that have historically been detected on or near our study area, although information available on carnivore surveys in Oregon was limited.

**METHODS**

**Study Area**

Our study area included portions of the Willamette (about 6900 km²) and Deschutes (about 7300 km²) National Forests in the northern Cascade Range of Oregon, with our efforts concentrated in the Mt. Jefferson, Mt. Washington, and Three Sisters wilderness areas (Fig. 1). Within Oregon, the Cascade Range extends the full distance from north to south borders and is divided into 2 ecoregions: the West Cascades and the East Cascades. Within the wetter West Cascades ecoregion (west slope of the Cascades), forests are dominated by Douglas-fir (*Pseudotsuga menziesii*). This ecoregion experienced a substantial reduction in old-growth Douglas-fir during the past century, but overall this ecoregion is considered to be relatively healthy within the state (ODFW 2006). The drier East Cascades ecoregion (east slope) is dominated by Ponderosa Pine (*Pinus ponderosa*) and Lodgepole Pine (*Pinus contorta*) and has experienced major forest structural and composition changes through altered fire regimes (fire suppression, wildfires), changing forest practices, and increasing urbanization and recreational use (ODFW 2006). Other vegetation on our study area included Silver Fir (*Abies amabilis*), Sub-alpine Fir (*Abies lasiocarpa*), Mountain Hemlock (*Tsuga mertensiana*), Western Hemlock (*Tsuga heterophylla*), and alpine meadows. Our study area has had 2 stand-replacing burns >5000 ha since 1996. The B & B Complex fires in summer 2003 covered approximately 36,720 ha between Mt. Jefferson and Cache Mountain, and the Pole Creek fire in summer 2012 involved approximately 10,760 ha in northeastern Three Sisters Wilderness and extending east outside of the wilderness area. Santiam Pass (1468 m in elevation), between the Mt. Jefferson and Mt. Washington wilderness areas, generally experiences snowfall during 10 mon of each year, with a monthly peak of 262 cm of snow depth during March (Western Regional Climate Center 2013). Snowfall and snow depth typically increase with increasing
elevation in the study area. Average minimum (−6.9°C) and maximum (22.8°C) daily temperatures occur during January and July, respectively (Western Regional Climate Center 2013).

Field Methods

Our study was conducted during October 2012–May 2013 and October 2013–June 2014, using non-invasive survey methods primarily to collect data (presence and distribution) on mammalian forest carnivores within the study area. We used 2 types of baited camera stations, elevated and ground, with the former designed for mammalian carnivores capable of climbing (American Marten, Wolverine) and the latter designed for both climbing and non-climbing mammalian carnivores (Red Fox). Elevated

FIGURE 1. Locations of baited camera stations (solid circles) implemented as part of a non-invasive survey of forest carnivores in 3 US Forest Service wilderness areas (hashed areas) and adjacent areas in the Deschutes and Willamette National Forests, Cascade Range, Oregon, October 2012–May 2013 and October 2013–June 2014.
stations included a wire cable secured between 2 trees and about 3 to 4 m aboveground, bait suspended by cable 2 to 3 m aboveground (or above snow, depending on presence of snow) near one of those trees, and during the 1st field season, a climbing platform and hair-snagging device designed to collect samples from Wolverine (Fig. 2; Magoun and others 2011). Ground stations consisted of bait wrapped in poultry fencing and secured about 1 m aboveground to the bole of a tree, with hair-snagging devices installed if Red Fox were suspected or known to be in the vicinity. Hair-snagging devices consisted of a series of gun brushes mounted horizontally around the tree base using corrugated plastic (Fig. 3; Figura and Knox 2010). Cameras were mounted 2 to 3 m (elevated) or about 2 m (ground) aboveground to nearby trees and positioned to obtain images that maximized the area where target species would likely be positioned while visiting either station type, but also allowing visual identification of species. Three stations consisted of both elevated baits and ground baits, which we refer to as ground stations because of increased access offered to wildlife species.

We non-randomly selected station locations based on topographical and ecological features such as avalanche chutes and the presence of Mountain Goats (Oreamnos americanus), winter access, and historical detections and current detections or reported sightings of carnivores, particularly Wolverines and Red Fox, to increase the probability of detections. However, we also selected other station locations in an attempt to distribute stations within our large study area, but within time and budgetary constraints, and to meet our objectives for other forest carnivores such as American Marten. Clumped locations of stations during our study generally were the result of increasing our ability to collect data (images, DNA samples) where Red Fox were known to occur or selecting a station location during the 2nd field season that was relatively close to a station that had been used during the 1st field season (Fig. 1).

We used infrared Bushnell Trophy Cam HD (Overland Park, KS) and non-infrared Trail Watcher model 2035 and 2040 (Monticello, GA) motion-sensing digital cameras at stations using bait that typically consisted of 5- to 20-kg portions of salvaged Black-tailed or Mule Deer (Odocoileus hemionus), Elk (Cervus canadensis), or American Beaver (Castor canadensis), depending on site location, station design, and availability of bait. We also used a skunk-essence- based lure (Gusto, Minnesota Trapline Products, Pen- nock, MN) as an attractant applied about 2 m aboveground on nearby trees. We recorded location (UTM) and elevation of each station using a handheld GPS unit. Bait and equipment were transported by non-mechanical means (horse, human) within wilderness areas. We attempted to monitor cameras every 2 to 6 wk, depending on weather conditions, avalanche risk, and other factors. Using digital images, we attempted to identify every mammalian species that visited each station, but we did not attempt to identify all smaller non-Carnivora mammals (such as Sciuridae). We did not attempt to estimate number of individuals of any given species at any given station, but rather defined detection at a given station as ≥1 image, where species identification was confirmed at that station.

RESULTS AND DISCUSSION

We collected a total of 111,148 digital images from 21 elevated and 39 ground stations over 3555 camera-days during both field seasons. Disparities between the 1st and 2nd field seasons (i.e., first field season = 24% of total number of images, 53% of total number of stations, 60% of total camera-days) were related to camera malfunctions, differences in amount of volunteer assistance, and our increasing knowledge of the study area. During the 2nd field season, 5 stations were located ≥400 m from the nearest station active during the 1st field season because those locations were assumed to be of high importance for detecting Wolverines, if present. Due to an error with a camera setting, 1 camera collected only digital videos, which we used to identify species detected at that station. Cameras were active at stations for an average of 59.3 d (SE = 6.9, range = 2 to 212). A minimum of 12 cameras were active at any given time during our study except during the first (construction of stations) and last (removal of stations) months of each field season. Elevation of stations ranged from 586 to 2237 m (median = 1548 m; Fig. 4). Stations were located, based on NatureServe Explorer (2014) ecological classification system,
in Silver Fir-Mountain Hemlock forests (50.0%), subalpine forests and woodlands (10.0%), western Oregon Douglas-fir-hemlock forests (10.0%), coastal and valley lowland riparian forests and shrublands (5.0%), Lodgepole Pine forests and woodlands (5.0%), Ponderosa Pine forests and woodlands (5.0%), Siskiyou mixed conifer forests and woodlands (5.0%), mixed conifer forests (3.3%), old field-clearcut (3.3%), and lava flows (1.7%). Three and 4 stations were located in the Pole Creek burn area and B & B Complex burn area, respectively. At least 15 different mammalian species, of which 12 were of the Order Carnivora, were detected during our study (Table 1).

We detected Red Fox at 23% of ground stations (Table 1, Fig. 3; n = 9 of 39 total ground stations: 27% of ground stations during 1st season, 21% during 2nd season; elevation range = 1545–1988 m for all detections). Our detections (and other evidence not reported here) of Red Foxes included areas near high human use (such as Hoozoo Ski Area, Mt. Bachelor Ski Area), and of each of the 3 primary pelage colorations (silver, cross, red). Ground stations with detections of Red Fox were located in Silver Fir-Mountain Hemlock montane forests (77.8%), Lodgepole Pine forests and woodlands (11.1%), and subalpine forests and woodlands (11.1%). Of the 5 ground stations located in previous stand-replacing burns, 2 stations
located in the Pole Creek burn resulted in a detection of ≥1 Red Fox. Preliminary genetic analysis provided additional evidence to suggest that Red Foxes on our study area are the indigenous Sierra Nevada subspecies (TL Hiller, unpubl. data).

Coyotes were detected at 4 of the ground stations that also detected Red Fox, including those located in the Pole Creek burn. Stations with detections of Coyotes were located in Silver Fir-Mountain Hemlock forests (41.7%), Lodgepole Pine forests and woodlands (25.0%), old field-clearcut (16.7%), mixed conifer forests (8.3%), and western Oregon Douglas-fir-Hemlock forests (8.3%).

We detected American Marten at 63% of all stations (Table 1, Fig. 2; n = 38 of 60 stations total: 72% of stations during 1st season, 54% during 2nd season; elevation range = 1252–2237 m for all detections). Martens seemed well distributed on our study area based on the majority of stations resulting in detections (Table 1). Stations with marten detections occurred in Silver Fir-Mountain Hemlock forests (73.7%), subalpine forests and woodlands (13.2%), Lodgepole Pine forests and woodlands (5.3%), alpine and subalpine habitats (2.6%), Siskiyou mixed conifer forests and woodlands (2.6%), and western Oregon Douglas-fir-Hemlock forests (2.6%). The percentage of total cameras with ≥1 marten detection by month was relatively consistent, but highest during January and lowest during May (Fig. 5). Martens typically avoid large, open expanses (such as those resulting from clearcuts or stand-replacing fires), but such areas may be traversed.
or serve as sink habitat and become increasingly used about 15 y post-disturbance (Soutiere 1979; Slough 1989; Paragi and others 1996; Gosse and others 2005). We had detections of martens in 3 of 4 stations within the area of the B & B Complex burn (about 10 y post-burn) and 2 of 3 stations within the area of the Pole Creek burn (1 to 2 y post-burn). Each of these was a stand-replacement burn with relatively little cover.

Unusual detections included Northern Raccoon (*Procyon lotor*) at an elevated station at 1814 m elevation in the Pole Creek burn area in TABLE 1. Wildlife species detected using non-invasive survey methods (2 types of baited camera stations), northern Cascades of Oregon, October 2012–May 2013 and October 2013–June 2014.

<table>
<thead>
<tr>
<th>Order</th>
<th>Species</th>
<th>Number of elevated stations (<em>n</em> = 21)</th>
<th>Number of ground stationsa (<em>n</em> = 39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carnivora</td>
<td>American Marten (<em>Martes americana</em>)</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Red Fox (<em>Vulpes vulpes</em>)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>American Mink (<em>Neovison vison</em>)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Long-tailed Weasel (<em>Mustela frenata</em>)</td>
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<td>2</td>
</tr>
<tr>
<td></td>
<td>Short-tailed Weasel (<em>Mustela erminea</em>)</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>American Black Bear (<em>Ursus americanus</em>)</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Coyote (<em>Canis latrans</em>)</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Bobcat (<em>Lynx rufus</em>)</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Northern Raccoon (<em>Procyon lotor</em>)</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>Mountain Lion (<em>Puma concolor</em>)</td>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>Striped Skunk (<em>Mephitis mephitis</em>)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Western Spotted Skunk (<em>Spilogale gracilis</em>)</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Rodentia</td>
<td>Sciuridae</td>
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<td>31</td>
</tr>
<tr>
<td></td>
<td>Lagomorpha</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Snowshoe Hare (<em>Lepus americanus</em>)</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Artiodactyla</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mule or Black-tailed Deer (<em>Odocoileus hemionus</em>)</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

a All ground stations had bait generally accessible to terrestrial mammals, but 3 ground stations also had elevated baits.

the Three Sisters Wilderness during January 2013; alternating detections of Northern Raccoon and American Marten occurred at this station. Northern Raccoons have been described in Oregon as “...common along the coast and foothill streams and lakes... but absent from the higher parts of the mountains” (Bailey 1936:315). Kaufmann (1982) stated that Northern Raccoons are rarely found in mountains above 2000 m. We are aware of 2 other Northern Raccoon detections within Oregon under conditions similar to ours. A detection occurred at 1535 m in elevation in the southern Cascades during a mustelid survey (Farrell and others 1996), and a recent detection occurred within the Eagle Cap Wilderness in northeastern Oregon at a baited camera station during January 2014 (B Ratliff, ODFW, Baker City, OR, pers. comm.). The latter detection occurred at 1810 m in elevation, and American Marten and Wolverine were also detected at this location during winter 2013-2014. We speculate that our detection was a potential dispersal event rather than a translocation because: (1) it was 19 km from the small town of Sisters, Oregon (human population = 2100); (2) raccoons have been documented to move ≥266 km (Priewert 1961; Lynch 1967); and (3) the translocation of raccoons is illegal in Oregon (ODFW 2012) and translocation to such a remote and roadless location seemed unlikely. Other unusual detections included Striped (Mephitis mephitis) and Western Spotted (Spilogale gracilis) skunks (elevation = 1559 and 1475 m, respectively) at ground stations about 8 km south of Camp Sherman, Oregon during November 2013, also at elevations much higher than expected.

During our study, we did not detect Wolverine, Fisher (Martes pennanti), Gray Wolf (Canis lupus), or Canada Lynx (Lynx canadensis), the last of which included only 17 records statewide during 1897–1993 (Hiller 2011). Verts and Carraway (1998) considered Wolverine observations in Oregon to be associated with unusual dispersal events by individuals and not representative of self-sustaining populations. Despite several efforts, no Wolverines have been confirmed in Oregon since 1992 based on ODFW records until Magoun and others (2013) detected 3 in northeastern Oregon. A Wolverine was confirmed in northern California during 2008, with evidence suggesting it was of Rocky Mountain origin, but no evidence confirming whether it dispersed, and if so, its dispersal path (Moriarty and others 2009). We had no evidence of Wolverines occurring within the northern Cascades of Oregon during our study,
although the Cascades may at minimum have served historically as a dispersal corridor based on documentation of individuals during past decades in California and Oregon (Aubry and others 2007).

During January–March 2014, <22 km south of our nearest baited camera station, ≥1 Fisher was confirmed through digital images at a baited camera station (elevation = 1080 m) near the Middle Fork Willamette River in the Willamette National Forest (B. Wolfer, ODFW, Springfield, OR, pers. comm.). This detection was approximately 19 km north of locations obtained during 2000 from a radiomarked Fisher from the nearest of 2 known populations in Oregon (J Kittrell, US Forest Service, Crescent, OR, pers. comm.; Lofroth and others 2010). During June 2014, the 1st documented reproduction of Gray Wolves in the Oregon Cascades since the 1940s occurred (ODFW 2014a). Oregon’s wolf population has steadily increased in both distribution and abundance (2013 estimated minimum = 64 wolves) since 2009 (ODFW 2014b). If this pattern continues, as has occurred in other western states, it would be logical to assume that the Oregon Cascades may have some level of resident packs during the coming decades.

The composition and distribution of mammalian carnivore communities in Oregon (and other states) has changed substantially during the past century and may continue to do so. Changes in forest management practices and the cessation of unregulated harvest (such as market hunting) and state or federal protections have benefitted wildlife species such as sensitive forest carnivores to varying degrees. As populations of Gray Wolves continue to recover in western states, a restructuring of predator communities may result (Dekker 1989; Levi and Wilmers 2012). Species such as Coyotes and Northern Raccoons have experienced range expansions for decades through anthropogenic landscape-scale effects, and potentially climate change (Moore and Parker 1992; Gehrt 2003, Larivière 2004). It is possible that these generalist species will also increase latitudinal distribution should climate change continue to create favorable conditions for them in areas previously unoccupied. In addition to our results, we also discussed detections that were not part of our study. As a whole, this further illustrates the importance of monitoring forest carnivore populations in an effort to collect data on presence and distribution in Oregon and within the Pacific Northwest. For example, additional research on Sierra Nevada Red Fox in the Oregon Cascades is critical to ascertain distribution, abundance, habitat requirements, potential hybridization with non-native subspecies, and assess ecological relationships with Coyotes (and potentially Gray Wolves) to make informed conservation and management decisions.

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